

EE 474 Lab 3: LKMs and Shift Registers



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1. Abstract


The main purpose of this lab is to introduce and explore the concepts of Kernel mode programming while optimizing the code done in the previous lab. First, an 8-bit shift register is designed in order to reduce the number of GPIO pins used. Second, a Kernel mode driver, LKM, is built to interface with the LCD screen on the board. From kernel mode, we developed a LKM that allows us to open, close, read, and write to the LCD.

2. Development:

1. Connecting to the Board

Establishing the proper connection to the board is essential to accomplish the goal of this lab. It is done using SSH networking protocol commands. The command used was `ssh root@192.168.7.2`. Once, the connection is established, programs could be loaded onto the board.

Beaglebone Black Pinout Diagram									
P9					P8				
Function	Physical Pins	Function	Function	Physical Pins	Function	Physical Pins	Function	Physical Pins	Function
DGND	1	2	DGND	1	DGND	1	DGND	2	DGND
VDD 3.3 V	3	4	VDD 3.3 V	3	MMC1_DAT6	3	MMC1_DAT7	4	MMC1_DAT7
VDD 5V	5	6	VDD 5V	5	MMC1_DAT2	5	MMC1_DAT3	6	MMC1_DAT3
SYS 5V	7	8	SYS 5V	7	GPIO_66	7	GPIO_67	8	GPIO_67
PWR_BTN	9	10	SYS_RESET	9	GPIO_69	9	GPIO_68	10	GPIO_68
UART4_RXD	11	12	GPIO_60	11	GPIO_45	11	GPIO_44	12	GPIO_44
UART4_TXD	13	14	EHRPWM1A	13	EHRPWM2B	13	GPIO_26	14	GPIO_26
GPIO_48	15	16	EHRPWM1B	15	GPIO_47	15	GPIO_46	16	GPIO_46
SPI0_CS0	17	18	SPI0_D1	17	GPIO_27	17	GPIO_65	18	GPIO_65
I2C2_SCL	19	20	I2C_SDA	19	EHRPWM2A	19	MMC1_CMD	20	MMC1_CMD
SPI0_DO	21	22	SPI0_SLCK	21	MMC1_CLK	21	MMC1_DAT5	22	MMC1_DAT5
GPIO_49	23	24	UART1_TXD	23	MMC1_DAT4	23	MMC1_DAT1	24	MMC1_DAT1
GPIO_117	25	26	UART1_RXD	25	MMC1_DAT0	25	GPIO_61	26	GPIO_61
GPIO_115	27	28	SPI1_CS0	27	LCD_VSYNC	27	LCD_PCLK	28	LCD_PCLK
SPI1_DO	29	30	GPIO_112	29	LCD_HSYNC	29	LCD_AC_BIAS	30	LCD_AC_BIAS
SPI1_SCLK	31	32	VDD_ADC	31	LCD_DATA14	31	LCD_DATA15	32	LCD_DATA15
AIN4	33	34	GND_ADC	33	LCD_DATA13	33	LCD_DATA11	34	LCD_DATA11
AIN6	35	36	AIN5	35	LCD_DATA12	35	LCD_DATA10	36	LCD_DATA10
AIN2	37	38	AIN3	37	LCD_DATA8	37	LCD_DATA9	38	LCD_DATA9
AIN0	39	40	AIN1	39	LCD_DATA6	39	LCD_DATA7	40	LCD_DATA7
GPIO_20	41	42	ECAPWMO	41	LCD_DATA4	41	LCD_DATA5	42	LCD_DATA5
DGND	43	44	DGND	43	LCD_DATA2	43	LCD_DATA3	44	LCD_DATA3
DGND	45	46	DGND	45	LCD_DATA0	45	LCD_DATA1	46	LCD_DATA1



LEGEND

- Power, Ground, Reset
- Digital Pins
- PWM Output
- 1.8 Volt Analog Inputs
- Shared I2C Bus
- Reconfigurable Digital

Figure 1. Pinout for the Beaglebone black board. Notice that the export reference to the GPIO pins is denoted by the number within the Function name. For example, the number used to denote Physical Pin 15, P9 is 48 (GPIO_48).

2. Connecting the hardware

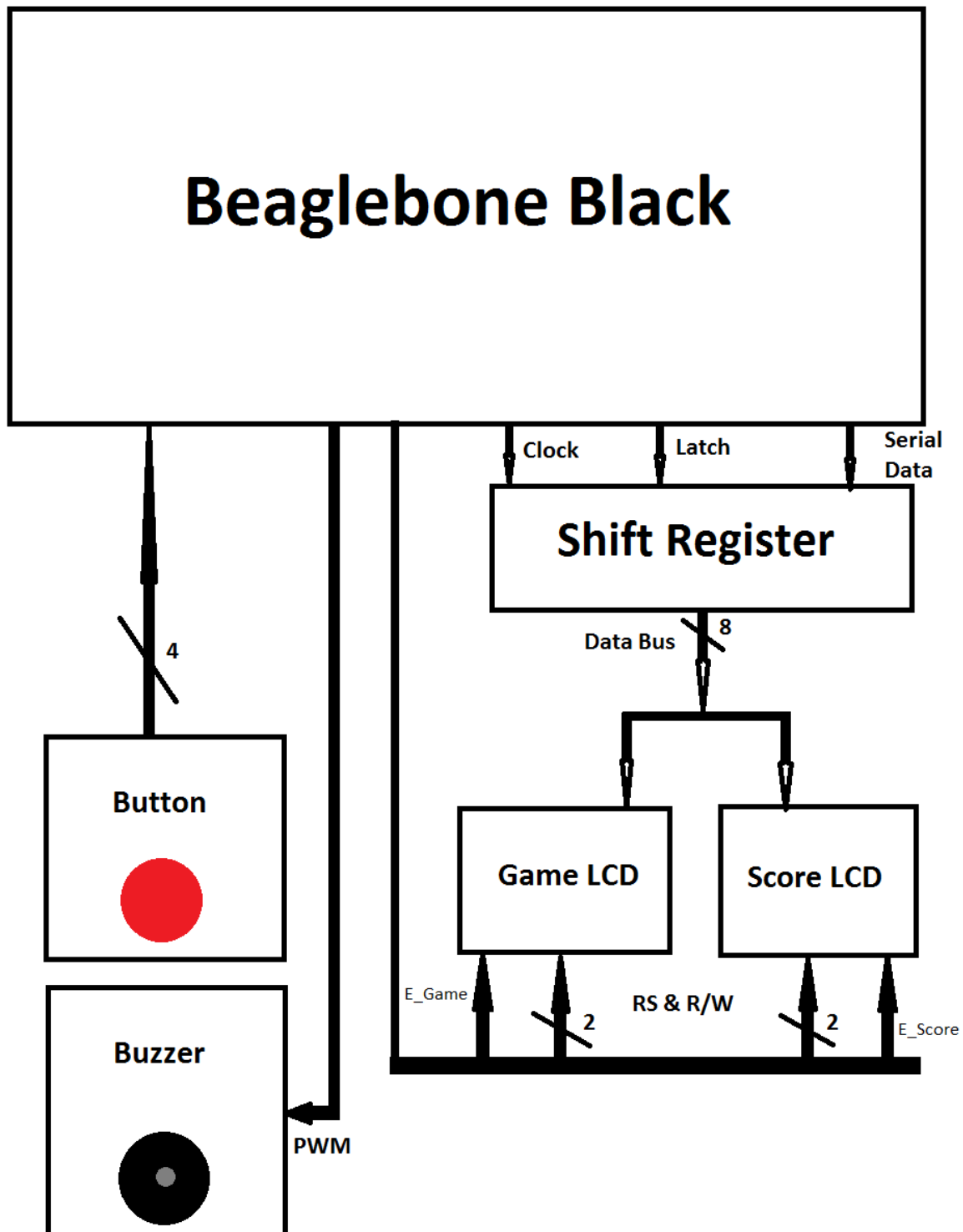


Figure 2. This is a block diagram that represents the interface between the LCD with the Beaglebone Black. Note that the buzzer is not defined within the LKM of either the button or the LCD drivers. The buzzer is defined in user space within the button Hero code that we made.

Table 1: The Pin Description for the LCD pins and Beaglebone Black pins

Pin No.	Symbol	External Connection	Function Description	Attached Beaglebone Pin
1	VSS	Power Supply	Ground	DGND
2	VDD	Power Supply	Supplies Voltage for logical operations (+5 V)	SYS 5V
3	V0	Adj Power Supply	Power supply for screen contrast	N/A
4	RS	MPU	Register select signal 0: Command, 1: Data	GPIO_PIN_68
5	R/W	MPU	Read/Write select signal 0: Write, 1: Read	GPIO_PIN_44
6	E_GAME	MPU	Operation enable signal. Sends on falling edge.	GPIO_PIN_60
7	E_SCORE	MPU	Operation enable signal. Sends on falling edge.	GPIO_PIN_26
8	DATA_	MPU	Low order bi-directional data bus lines	GPIO_PIN_45
9	LATCH_	MPU	Latch signal input	GPIO_PIN_47
10	CLOCK_	MPU	Clock signal input	GPIO_PIN_67
11	BUZZER_	MPU	PWM buzzer input	GPIO_PWM_14

2. Transferring cross-compiled files to the board

Files are transferred and cross-compiled directly to the board using the given makefile that compiles C code into LKM. We were able to set the makefile so that it compiles both the lcd_driver.o and button_driver.o at the same time. The compiler used in the makefile is the arm-linux-gnueabi-hf- compiler.

Table 2. The targets of the Makefile and their individual effects

Target	Function Description
default	Creates Kernel mode driver for the LCD screens and button
clean	Removes the transferred file from the Beaglebone

3. Initializing the LCD

Before being able to use the LCD, the LCD must be initialized by sending a specific sequence of instructions after the LCD has been power ON. Our group decided to use the 8-Bit LCD Interface in order to access more characters. The instruction sequence is shown below in Figure 3.

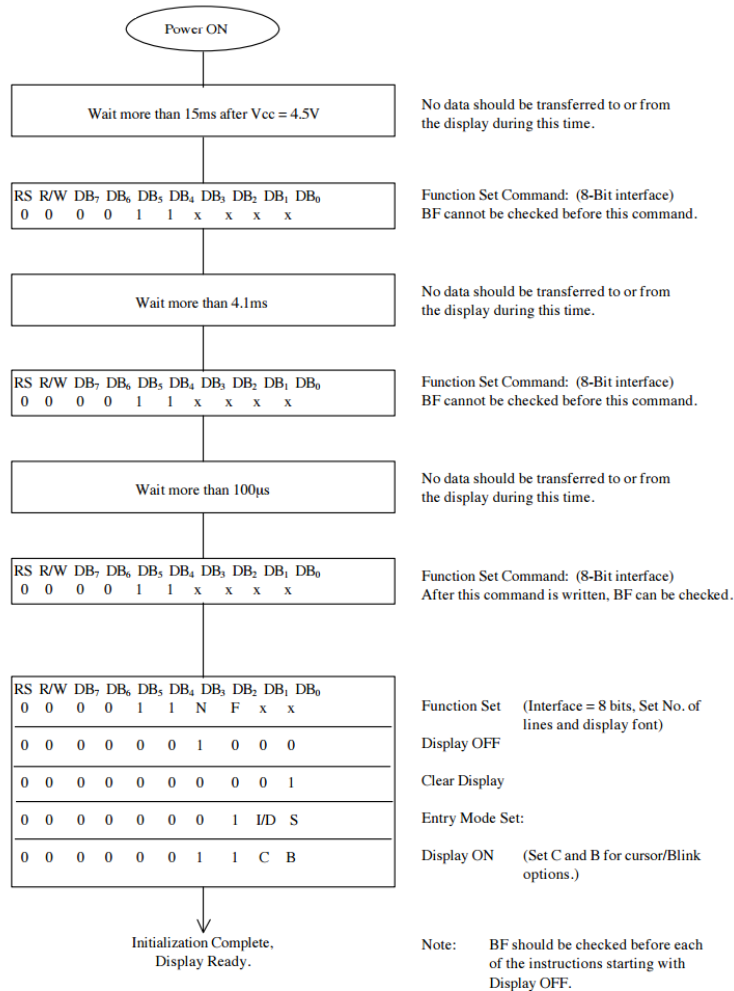


Figure 3. The instruction sequence used to initialize the NHD-0216BZ-FL-YBW LCD display to 8-bit. Note that we initialized one LCD with an 8-bit interface, 2 lines, 5x8 dot font, increment cursor mode, no display shift, cursor OFF, and blink OFF. The other

LCD was initialized to an 8-bit interface, 1 line, 5x10 dot font, decrement cursor mode, no display shift, cursor ON, and blink ON.

1. Shift Register

In order to reduce the number of GPIO pins used to interface with the LCD display we designed an 8-bit shift register. As a result, only three GPIO pins, clock, latch, and data, were used to replace DB7...DB0 for two LCD screens.

2. Kernel Mode

In the second part of the lab, we designed a kernel mode device driver for the LCD screens and a button used to navigate the Button Hero game. It can execute any instruction on the CPU without waiting and it has access to all of the memory addresses.

3. Button Hero Game

Lastly, we designed a Button Hero game in user space mode. The game is executed on two LCD screens and the control is done using a button. A random sequence of five direction characters, up, down, left, right, and press, is generated and then the button is used to mimic the character on the screen. As the game progresses, the first LCD screen is used to play the game and the second one displays the score and the misses.

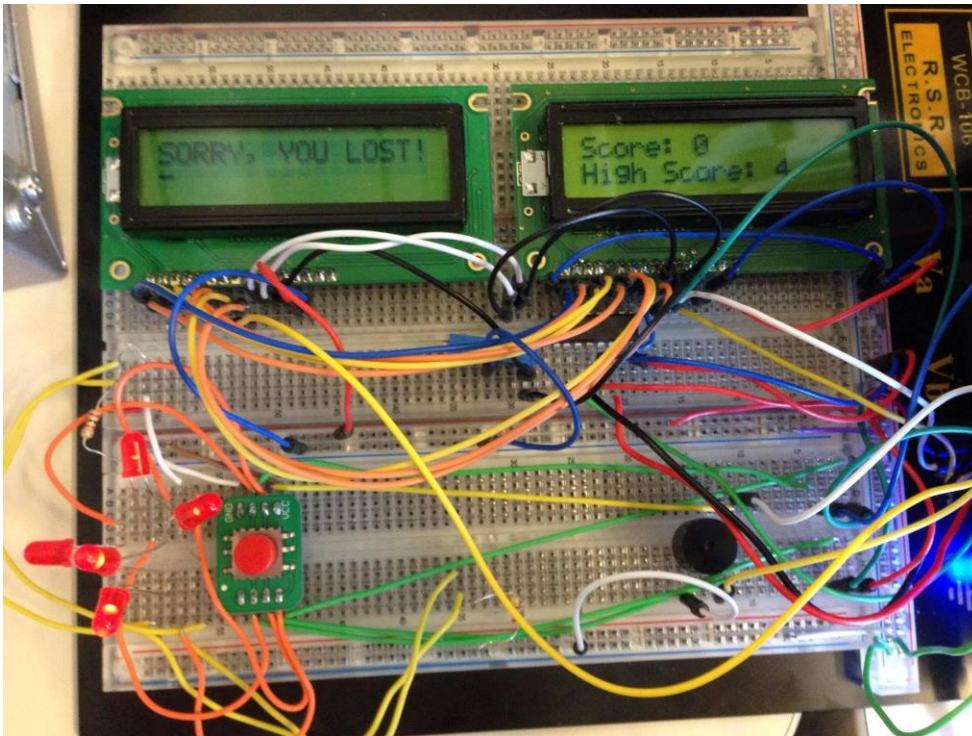


Figure 4. Overall system design with two LCD screens, five LEDs, button, and a buzzer with the Button Hero game results on the screens.

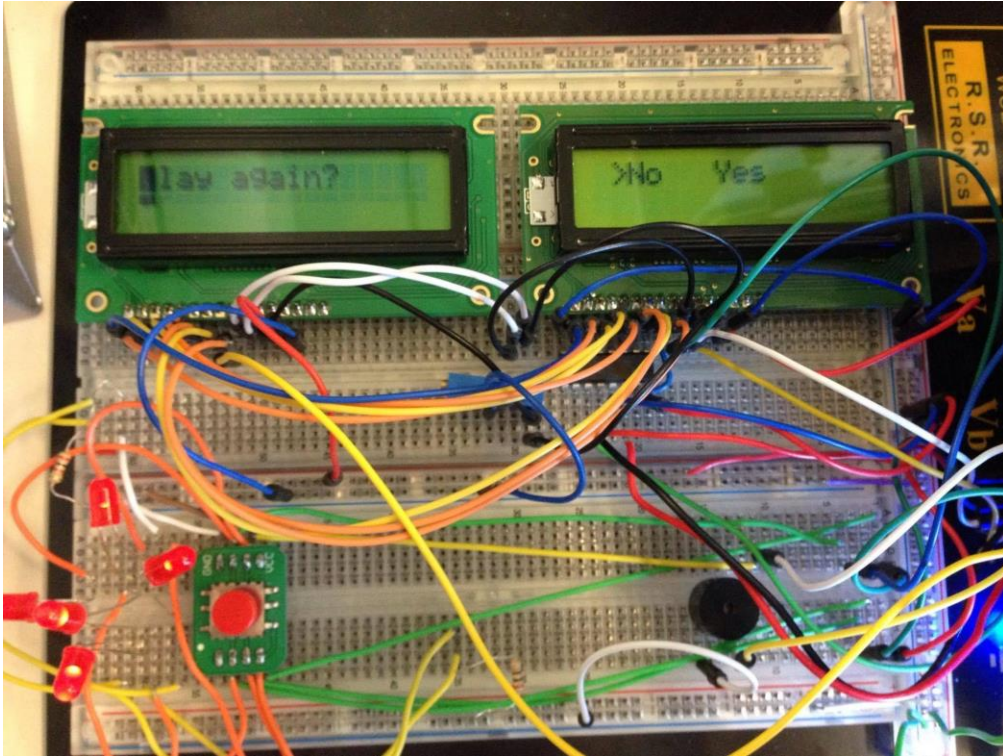


Figure 5. LCD screens with the main menu after the game is played

3. Discussion

While working on this lab we were able to explore the design of kernel mode device drivers and integrate it with the game in the user space.

4. Conclusion

The main purpose of this lab was to design a shift register to decrease the number of GPIO pins used. As a result, instead of using eight GPIO pins for each of the two 8-bit LCD screens, only three were used: clock, latch, and data.

Then, kernel mode device drivers were created to interface with the LCD screens and a button for the game.